step forward in the given direction.

$$\forall x, y \;\; LocationToward([x,y], 0) = [x+1, y]$$
$$\forall x, y \;\; LocationToward([x,y], 90) = [x, y+1]$$
$$\forall x, y \;\; LocationToward([x,y], 180) = [x-1, y]$$
$$\forall x, y \;\; LocationToward([x,y], 270) = [x, y-1]$$

From the map, it is possible to tell which square is directly ahead of the agent, or indeed of any agent $p$ at any location $l$:

$$\forall p, l, s \;\; At(p, l, s) \;\Rightarrow\; LocationAhead(p, s) = LocationToward(l, Orientation(p, s))$$

It is also useful to define adjacency:

$$\forall l_1, l_2 \;\; Adjacent(l_1, l_2) \;\Leftrightarrow\; \exists d \;\; l_1 = LocationToward(l_2, d)$$

- Whatever is known about the contents of the locations (geographical details on the map). In what follows we assume that the locations surrounding the $4 \times 4$ cave contain walls, and other locations do not. Sometimes the agent knows this kind of information to start, and sometimes it does not.

  $$\forall x, y \;\; Wall([x,y]) \;\Leftrightarrow\; (x=0 \lor x=5 \lor y=0 \lor y=5)$$

- What the actions do to location. Only going forward changes location, and then only if there is no wall ahead. The successor-state axiom for location is

  $$\begin{aligned} \forall a, d, p, s \;\; & At(p, l, Result(a, s)) \;\Leftrightarrow \\ & [\;(a = Forward \land l = LocationAhead(p, s) \land \neg Wall(l)) \\ & \lor (At(p, l, s) \land a \neq Forward)\;] \end{aligned}$$

- What the actions do to orientation. Turning is the only action that changes orientation. The successor-state axiom for orientation is

  $$\begin{aligned} \forall a, d, p, s \;\; & Orientation(p, Result(a, s)) = d \;\Leftrightarrow \\ & [\;(a = Turn(Right) \land d = Mod(Orientation(p, s) - 90, 360)) \\ & \lor (a = Turn(Left) \land d = Mod(Orientation(p, s) + 90, 360)) \\ & \lor (Orientation(p, s) = d \land \neg(a = Turn(Right) \lor a = Turn(Left)))\;] \end{aligned}$$

In addition to keeping track of location and the gold, the agent should also keep track of whether the wumpus is alive or dead. We leave the problem of describing *Shoot* as an exercise.

## 7.7 DEDUCING HIDDEN PROPERTIES OF THE WORLD

Once the agent knows where it is, it can associate qualities with the *places* rather than just the situations, so, for example, one might say that if the agent is at a place and perceives a breeze, then that place is breezy, and if the agent perceives a stench, then that place is smelly:

$$\forall l, s \;\; At(Agent, l, s) \land Breeze(s) \;\Rightarrow\; Breezy(l)$$
$$\forall l, s \;\; At(Agent, l, s) \land Stench(s) \;\Rightarrow\; Smelly(l)$$